MODULAR PATCH ANTENNA PROVIDING ANTENNA GAIN DIRECTION SELECTION CAPABILITY

This invention relates to modular patch antennas. These antennas are especially adapted for use in receiving audio information and data from both terrestrial and satellite transmitters.

These modular patch antennas are especially adapted for use in receiving both satellite-transmitted and terrestrially-transmitted digital audio/data radio services. The following patents and patent applications related to these systems are hereby incorporated by reference as though fully set forth here:

U.S. Patent No.	Title	Issue Date
6,564,053	Efficient High Latitude Service Area Satellite Mobile Broadcasting Systems	May 13, 2003
6,023,616	Satellite Broadcast Receiver System	Feb. 8, 2000
5,864,579	Digital Radio Satellite And Terrestrial Ubiquitous Broadcasting System Using Spread Spectrum Modulation	Jan. 26, 1999
5,794,138	Satellite Broadcast System Receiver	Aug. 11, 1998
5,592,471	Mobile Radio Receivers Using Time Diversity To Avoid Service Outages In Multichannel Broadcast Transmission Systems	Jan. 7, 1997
5,485,485	Radio Frequency Broadcasting Systems And Methods Using Two Low-Cost Geosynchronus Satellites And Hemispherical Coverage Antennas	Jan. 16, 1996
5,319,673	Radio Frequency Broadcasting Systems And Methods Using Two Low-Cost Geosynchronus Satellites	Jun. 7, 1994

EPO Patent	Title	Date Of Pub.
EP 0 959 573 A2 EP 990303823	System For Efficiently Broadcasting Via Satellite To Mobile Receivers In Service Areas At High Latitude	Nov. 24, 1999

Int'l. Pub. No.	Title	Intl. Pub. Date
WO 01/33729 A1	Method And System For Providing Geographic Specific Services In A Satellite Communications Network	10 May 2001
WO 01/33720 A3	Method And Apparatus For Selectively Operating Satellites In Tundra Orbits To Reduce Receiver Buffering Requirements For Time Diversity Signals	10 May 2001

Satellite Digital Audio Radio Services (SDARS), such as those provided by Sirius Satellite Radio Inc. and XM Satellite Radio, Inc, are examples of a wireless content delivery system implementation that uses both satellite and terrestrial transmitters to deliver audio and data content to users located at various parts of a service area. In such systems, the receiver usually works with satellite signals in rural areas, and, where terrestrial sites exist, with terrestrial signals in urban areas. Generally, satellites are visible to receiver antennas when the satellites are at or above about 20° elevation angle in the sky. The terrestrial networks are visible to receiver antennas at or about below 10° elevation angle in the horizontal direction.

The SDARS systems provide various broadcast content (i.e. audio and data) delivery services over a large system service area, e.g. CONUS (the mainland United States). Signal delivery is made to subscribing receivers within a system service area from geo-stationary or geo-synchronous satellite networks, simultaneously with a ground-based terrestrial signal delivery network. Service delivery performance enhancement of these broadcast signals using selectable-beam antenna operation capability is an object of this invention.

This invention relates to methods and systems that comprise modular patch antennas that improve the operational performance of the Satellite-based Direct Audio Radio Services (SDARS) (e.g. Sirius Satellite Radio) by user modification of such systems. These patch antennas preferably comprise first and second modules. The first module comprises a first metal or metal plated radiating layer, a second, or middle, dielectric layer, and a third metal or metal plated ground layer.

This invention also relates to methods and systems for enabling selectable receiver antenna beam patterns that provide selectable operational performance to receivers that are for use with both satellite and ground-based terrestrial networks.

Although the invention could apply to a wide range of frequencies, preferred embodiments of SDARS antennas receive signals with frequencies in a range of about 2320 MHz to about 2345 MHz. For SDARS applications, the radiating layer comprises, in preferred embodiments, metal or metal plating such as Ag, Au, Cu, Ni, or Al. Preferably, this layer of metal or plating has a length in the range of about 30 to about 60 mm, and a width in the range of about 30 to about 60 mm.

The dielectric layer, in preferred embodiments, comprises substances that can have different dielectric constants, such as Teflon, PTFE (polytetrafluoroethylene), glass, ceramic, aluminum, polymers, silica, or quartz. This layer preferably has a height or thickness in the range of about 1 to about 5 mm, and a perimeter in the range of about 35 to about 65 mm.

The ground layer, in preferred embodiments, comprises a metal or metal plating such as Ag, Au, Cu, Ni, or Al. This layer of metal or plating has a width in the range of about 35 to about 65 mm, and a length in the range of about 35 to about 65 mm.

In some embodiments, the perimeter of each of the three layers is substantially the same, and is in the range of about 30 to about 60 mm. Preferably, the antenna is square, rectangular, round or elliptical in shape.

A second modular component comprises a frame that attaches to/fits onto the periphery of the first module. This frame preferably has a length and a width in the range of about 40 to about 75 mm, a height or thickness in the range of about 1 to about 5 mm, and preferably comprises the same material as the dielectric layer of the first module, but can comprise a different dielectric material, if desired. Alternatively, the second module may be a frame that comprises the same three layers as the first module, and, preferably, has all three layers of substantially the same size and shape as the three layers of the first module.

The first module of the modular patch antenna, in preferred embodiments, has a circularly polarized gain at elevation angles of about 40° or more in the sky, in the range of about +5 to about +6 dBic, and a vertically polarized gain, at 0° elevation angle, in the range of about -6 to about -7 dBi. To receive terrestrially transmitted SDARS signals, the patch antenna preferably has a vertically polarized gain, at 0° elevation angles, of at least about –5 dBic in circular polarization, which translates to about -2 dBi in vertical polarization, assuming that the left and right hand polarization components have the same magnitude.

For the patch antenna to receive satellite SDARS signals, the circularly polarized gain of the antenna is preferably about +3 dBic at a minimum. Preferably, the increase in the dielectric frame size increases the circularly polarized gain of the antenna at 0° to about -5 dBic from about -8 dBic, where the antenna patch has a periphery in the range of

about 50 to about 175 mm, thus increasing the vertically polarized gain of the antenna at 0° elevation angle by about 3 dB.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention can be better understood by reference to the accompanying drawings, in which:

Figure 1 shows an embodiment of a first module of a modular patch antenna, optimized for reception of satellite radio transmission;

Figure 2 shows the circular polarization gain pattern of the patch antenna module of Figure 1;

Figure 3 shows the patch antenna of Figure 1 combined with a second module, namely a frame that extends the size of the dielectric layer of first module, thus optimizing the antenna for reception of terrestrial radio transmission;

Figures 4 and 5 show the measured circular polarization gain pattern of the modular patch antenna of Figure 3;

Figure 6 shows a first embodiment of an assembly of the first and second patch antenna modules; and

Figure 7 shows a second embodiment of a two-module modular patch antenna.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a first patch antenna module 10 comprising a first metal radiating layer 11, a middle dielectric layer 12, and a third ground plane layer 13. Preferably, module 10 is 42 cm long, 42 cm wide and 17 cm thick

Figure 2 shows the measured gain pattern of the antenna module of Figure 1. This antenna provides a left-hand circularly polarized gain (LHCP) of up to 7 dBic LHCP at around 90° elevation. This gain level is favorable for reception of signals from SDARS satellites that are at high elevations, e.g. 50° and above.

Figure 2 also shows that the antenna module of Figure 1 provides a left-hand circular polarized gain of about –8 dBic at 0° elevation angle at the horizontal direction. Terrestrial signals are vertically linear polarized. At low elevations, this module's vertically linear polarized signal reception gain is 3 dB higher than its left-hand circularly polarized signal reception gain pattern. This is because both the left-hand and the right-hand polarized gain patterns are at equal levels, producing a 3 dB higher vertical gain of –5 dBi vertical polarization (VP) gain at low elevations. Normally, 0 dBi VP gain is expected for normal terrestrial signal reception. Thus, the level achieved with the module of Figure 1 is 5 dB below the acceptable level for terrestrial reception.

Terrestrial signal pickup requires the antenna beam to concentrate at low elevation angles. To obtain better terrestrial signal reception from the antenna of Figure 1, extending the patch dielectric size yields an increase at 0° elevation angle in the horizontal direction.

Figure 3 shows the module 10 of Figure 1 combined with a second module 14, an extended dielectric layer forming a frame around the first module. The perimeter of the

dielectric, and of the two-module antenna, is 50 mm by 50 mm. The antenna's circularly polarized gain at 0° increases to –5 dBic, as compared to –8 dBic for the first module of Figure 1 alone.

Figure 4 shows that the antenna of Figure 3 has a –5 dBic LHCP or –2 dBic vertically polarized gain at 0° elevation angle at the horizontal direction, enhancing the terrestrial signal reception by 3 dB. However, this antenna sacrifices the high gain needs of satellite signal reception at high elevations at the vertical direction by about 2 dB.

Figure 5 plots the gain curves shown in Figure 2 and Figure 4 on the same graph. The antenna of Figure 3 has 2 dB less gain at the satellite signal reception direction at about a 90° elevation angle.

As Figure 6 shows, a second module can be added to the first module manually or otherwise. The first module alone provides good satellite signal reception. The first and second modules together, as Figure 6 shows, provide good terrestrial SDARS signal reception.

As Figure 7 shows, a second embodiment of a modular antenna 15 comprises a first module, as shown in Figure 6, and a second module that is a frame, This frame comprises the same three layers as the first module, namely a first metal radiating layer 18, a second or middle dielectric layer 19, and a third metal ground layer 20. By contrast, the patch antenna embodiment of Figure 6 consists solely of the dielectric material of the middle layer in the first module.